(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
3 May 2001 (03.05.2001)

PCT

(10) International Publication Number
WO 01/30652 A1

(51) International Patent Classification[7]: B64C 29/00, B64D 27/24

(21) International Application Number: PCT/IB00/01513

(22) International Filing Date: 23 October 2000 (23.10.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
1959/99 26 October 1999 (26.10.1999) CH
09/475,325 30 December 1999 (30.12.1999) US

(71) Applicant and
(72) Inventor: BUCHER, Franz [CH/CH]; Rebgasse 17, CH-4058 Basel (CH).

(74) Agent: E. BLUM & CO.; Vorderberg 11, CH-8044 Zürich (CH).

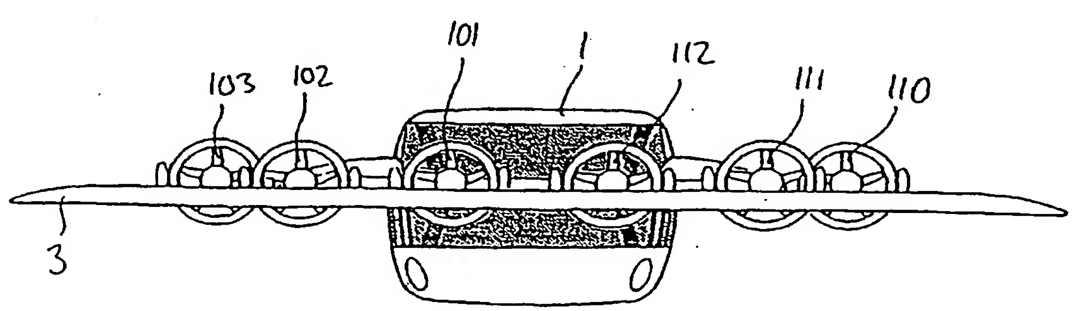
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: AIRCRAFT AND METHOD FOR OPERATING AN AIRCRAFT



(57) Abstract: The aircraft comprises a central cabin (1), which is located in the center of a circular wing (3). Several pivotal electric drive units (102-112) are arranged in a gap between the central cabin and the circular ring. In hover flight, the drive units are pivoted to generate a lift. When the aircraft goes into cruise flight, the drive units are pivoted to generate a forward thrust. Attitude and movements of the aircraft can be controlled by individual or common adjustment of the thrust and pivot angle of the drive units. Due to its simple design, the aircraft is economic and safe in operation. Still it has a high payload for its size.

WO 01/30652 A1

Aircraft and method for operating an aircraft

Cross References to Related Applications

This application claims the priority of Swiss patent application 1959/99, filed October 26, 1999, as well as of US patent application 09/475325, filed December 30, 1999, the disclosures of which are incorporated herein by reference in their entirety.

Technical Field

The invention relates to an aircraft and a method for its operation, in particular an aircraft with electrically driven motors.

Background Art

Modern aircraft must combine a high level of safety with economic efficiency. Furthermore, they should be adaptable for various applications.

A very versatile concept is provided by aircraft of the VTOL type, such as it is e.g. disclosed in US 5 419 514. Even though various designs have been proposed in this field, none of them has led to an aircraft that fulfils the requirements of modern commercial flight, in particular in view of safety and efficiency.

Disclosure of the Invention

Therefore, the problem to be solved is to provide an aircraft and a method for operating an air-

craft that provide a high level of safety and economic efficiency.

This problem is solved by the independent claims.

According to the invention, the power for the drives is generated by a combustion engine driving an electric generator. The power from the generator is used by the electrically operated drive units for generating lift and forward thrust of the aircraft. This combines the good ratio between weight and energy storage of a combustion engine with the reliability and fast response of electric motors. Since the engine drives a generator only, its operating parameters are exposed to lesser variations than those of conventional aircraft engines, which reduces the risk of defects and increases efficiency.

Some or preferably all of the drive units can be pivoted individually, such that their thrust can be adjusted according to demand. Since they use electric motors and no combustion engines, their reliable operation is not impaired by the pivotal movements. The drive units can be pivoted from a vertical position up to a horizontal position. In the vertical position, they generate a lift that carries the aircraft in hover flight. In the horizontal position, they generate a forward thrust for a cruise flight of the aircraft.

The drive units are preferably designed to be ducted fans comprising at least one fan or impeller arranged in a tube-like hosing. Such ducted fans reach very high flow velocities and generate a low amount of noise.

By arranging the drive units on a circle, a configuration that is especially stable and easy to control is provided. Preferably, the aircraft comprises a central cabin and a circular wing arranged around the cabin. The drive units are arranged between the cabin and the circular wing. A design of high symmetry is preferred, where a gap for receiving the drive units is pro-

vided between the central cabin and the circular wing, because such an aircraft can be assembled from few, simple units.

In their horizontal position, the thrust axes of the drive units should be arranged above the central plane of the circular wing, such that the airflow on its surface is increased and lift is improved.

Preferably, at least five drive units are used, because when using only four drive units, the loss of only one of them leads to a configuration that is impossible to control in most situations.

Also, it is preferred not to arrange the drive units on a line, but e.g. in a circle, because such an arrangement gives a safe control for pitch and roll movements. This is especially important during transition from hover to cruise flight, where substantial pitch moments have to be compensated.

The aircraft can be operated in hover flight and cruise flight. In hover flight, the drive units are pivoted downwards to generate a lift for keeping the craft in the air. In cruise flight, the drive units are pivoted backwards to generate a forwards thrust, wherein the lift is dynamically generated by the profile of the fuselage.

The attitude of the aircraft, i.e. its pitch, roll and yaw can be controlled by pivoting the drive units and adjusting their thrust.

Brief Description of the Drawings

The invention will be better understood and objects other than those set forth above will become apparent when consideration is given to the following detailed description thereof. Such description makes reference to the annexed drawings, wherein:

Fig. 1 is a front view of an embodiment of the invention in cruise flight,

Fig. 2 is a sectional view of the craft of Fig. 1 in take-off position,

Fig. 3 is a horizontal, sectional view of the craft of Fig. 2 and

Fig. 4 is a partially sectional view of a drive unit with adjustable outlet diameter.

Modes for Carrying Out the Invention

The basic design of a preferred embodiment of the aircraft is shown in Figs. 1 - 3. It comprises an elongate central cabin 1 arranged in the center of a central disc 2. A circular wing 3 is located concentrically around central disc 2. A ring-shaped gap 4 is arranged concentrically to and around central disc 2 and cabin 1. Radial spokes 5 are extending through gap 4. Twelve drive units 101 - 112 are located between the spokes 5 along the inner side of circular wing 3. The design and function of these drive units are explained in detail below.

As shown in Figs. 2 and 3, the present embodiment of the aircraft offers space for two pilots and six passengers. Cabin 1 further provides room for a control console 10 and an entrance 11. Four extensible legs 12 mounted on cabin 1 are used for parking and taxiing.

Two combustion engines 14 are arranged in central disc 2 lateral to cabin 1, each driving a generator 15. Generators 15 provide power for feeding the electrically driven drive units 101 - 112. The engines 14 and generators 15 are dimensioned such that there is sufficient power for a safe landing even after failure of one engine or generator.

Each drive unit comprises an electrically driven ducted fan with an impeller or ventilator 20 and an electric motor. The impeller or fan 20 is located co-

axially in a tube-shaped duct 22. Duct 22 is pivotally mounted between two arms 24, 25. The pivotal position of the ducted fan is controlled by an electric actuator in a range of more than 90°. In particular, the drive units can be pivoted from the horizontal position shown in Fig. 1, where they generate a forward thrust for the aircraft, into the vertical position of Fig. 2, where they generate a lifting thrust.

As mentioned before, all drive units are fed by the generators 15, wherein the power of each drive unit is individually controlled by a schematically shown control unit 29. Control unit 29 can also control the pivotal position of each drive unit individually. All control signals required for this purpose are computed from the pilot's flight orders. The pilot does not need to worry about the adjustment of the individual components but merely indicates the parameters that he is interested in, such as pitch, yaw, and speed of his aircraft.

The aircraft can be operated in hover and cruise flight, and it can safely handle the transition between these two states.

In hover flight as well as during starting and landing, the drive units 101 - 112 are pivoted such that they generate an airjet 30 directed downwards. This corresponds to the position shown in Fig. 2. The lift generated in this way is sufficient for keeping the fully loaded and tanked aircraft in hover.

Attitude and displacements of the craft in hover flight can be adjusted by the power and pivotal angles of the drive units 101 - 112.

For adjusting lift, the power of all drive units can be increased or decreased simultaneously. A roll of the craft is preferably controlled by reducing or increasing the power of the lateral drive units 103, 104, 109, 110, pitch by reducing or increasing the power of the forward and aft drive units 101, 112, 106, 107 and

yaw by opposite pivoting the lateral drive units 103, 104, 109, 110.

Lateral offset of the craft can be achieved by reducing the thrust of the drive units on one side, which generates a slight roll resulting in a slightly lateral thrust.

Forward and backward movements of the craft can e.g. be controlled tilting all drive units.

In cruise flight with high velocity all drive units are preferably arranged parallel to flight direction F, as it is shown in Fig. 1, and they generate an airjet directed backwards and thereby a thrust for forward movement. The lift is generated by the aerodynamic profile of the craft (circular wing and cabin).

For attitude control in cruise flight, the pivotal angle and/or thrust of the drive units are adjusted. No flaps, rudders or ailerons are required.

In transition between hover and cruise flight, the drive units are brought from the vertical position of Fig. 2 and 3 into the horizontal position of Fig. 1. For this purpose, all drive units can e.g. by pivoted simultaneously and slowly about 90°. Alternatively, the transition can be started by pivoting only a part of the drive units while the other drive units remain directed downwards.

The present embodiment of the craft is designed for vertical landing. For emergency landings, a parachute is arranged in the craft, which, together with the large wing area, is sufficient to break the fall sufficiently. In case of an emergency landing, the spring damped legs 12 provide a crumple zone.

In case of a failure of drive power, the drive units can still be pivoted and be used as flaps, such that a gliding flight is possible.

The embodiment of the aircraft shown in Figs. 1 - 3 has an outer diameter of approximately 8 meters and a wing area of approximately 29 m^2. It can be made of

synthetic materials and has an empty weight of approximately 2 tons. The maximum take off weight is 3.6 tons with a redundant engine power of 2 × 1600 horse power and a total drive unit power of 100 kW. The aircraft can easily be scaled to different sizes.

Depending on the size of the craft, the number of drive units can be varied. At least five, preferably at least six drive units are preferred.

Because of the high symmetry of the craft and the application of several, identical drive units, the production as well as spare parts management and maintenance are substantially simplified. At the same time, the aircraft has high stability.

In the present embodiment, circular wing 3 of the craft is completely round. It is, however, possible to build a circular ring from several straight wing sections arranged substantially tangential around cabin 1. Or the wing can have oval shape. The term "circular wing" used in the claims is to comprise all such embodiments.

Other wing shapes, in particular triangular wings, could also be used.

The present craft is suited as passenger or cargo vehicle. Due to its ability to take off vertically, it can also be used in situations where space is limited.

Since several electric motors are used for the drive units, the aircraft can react very quickly when applied forces vary, and it is very mobile. Furthermore, since many drive units are being used, the individual motors are comparatively small such that they can react quickly.

During hover flight, the velocity of the aircraft is fairly small while the thrust to be generated by the drive units 101 - 112 must be fairly high. During cruise flight, the velocity of the aircraft is high while the thrust can be smaller than during hover flight. Hence, it is preferred to design the drive units in such a way that they provide high thrust for hover flight,

while they provide a high exit air velocity for cruise flight.

A preferred embodiment of the drive units fulfilling this requirement is shown in Fig. 4. As can be seen, the air outlet 40 of the drive unit is formed by a plurality of guide plates 42 arranged for forming a flared opening. The diameter D of the outlet with the guide plates 42 in the position of Fig. 4 is larger than the outlet diameter without the guide plates 42. Typically, the diameter D can e.g. be 95 cm with the guide plates 42 and 65 cm without them. To decrease the outlet diameter, guide plates 42 can be retracted into duct 22. Hence, the arrangement of Fig. 4 with extended guide plates 42 and large outlet diameter D is used for hover flight, while the guide plates 42 are retracted for cruise flight.

Alternatively to retracting the guide plates 42 into duct 22, the guide plates 42 can be constructed to be pivoted towards the axis of the drive unit, thereby decreasing diameter D without being retracted.

Other arrangements for decreasing the outlet diameter of the drive units, such as iris arrangements or stopper plates closing part of the output opening are known to a person skilled in the art.

Guide plates 42 can be actuated by dedicated servo motors. However, preferably, their movement is coupled to the pivot movement of the drive units such that the diameter D is decreased automatically when the drive units are pivoted from their vertical position into their horizontal position.

Alternatively or in addition to using an adjustable outlet diameter D, the blade angle of impeller or ventilator 20 can be adjustable. It is increased in cruise flight and decreased in hover flight.

While there are shown and described presently preferred embodiments of the invention, it is to be distinctly understood that the invention is not limited

thereto but may be otherwise variously embodied and practiced within the scope of the following claims.

Claims

1. An aircraft comprising
a central cabin (1),
a wing (3) extending at least partially around the cabin,
at least one generator (15) for generating electrical power,
at least one engine (14) for driving said generator (15), and
electrically driven drive units (101 - 112) for generating lift and forward thrust, wherein at least part of the drive units are pivotal from a vertical position to a horizontal position, and
means for adjusting the power of at least part of the drive units (101 - 112) individually,
wherein in said vertical position the drive units (101 - 112) are adapted to generate a lift sufficient for lifting the weight of the aircraft, and wherein in said horizontal position said drive units are adapted to generate a forward thrust while said lift is generated aerodynamically by said cabin (1) and said wing (3).

2. The aircraft of claim 1 wherein at least some of said drive units are pivotal individually.

3. The aircraft of claim 2 wherein each of the pivotal drive units is pivotal about a pivoting axis, wherein said pivoting axes are parallel to each other and perpendicular to a forward direction of said aircraft.

4. The aircraft of one of the preceding claims wherein said drive units (101 - 112) comprise ducted fans.

5. The aircraft of claim 4 wherein the ducted fans have a variable outlet diameter.

6. The aircraft of claim 5 wherein the ducted fans have a retractable, flared outlet (40).

7. The aircraft of one of the claims 5 or 6 wherein the outlet diameter is decreased by pivoting the drive units from the vertical position into the horizontal position.

8. The aircraft of one of the preceding claims wherein the drive units (101 - 112) are arranged on a circle.

9. The aircraft of one of the preceding claims wherein said drive units (101 - 112) are arranged between the cabin (1) and said wing (3).

10. The aircraft of one of the preceding claims wherein the wing (3) is a circular wing.

11. The aircraft of one of the preceding claims comprising a substantially circular gap (4) between the cabin (1) and the wing (3), wherein the drive units (101 - 112) are arranged in the gap.

12. The aircraft of one of the preceding claims wherein a thrust axis of the pivotal drive units (101 - 112) can be pivoted to a horizontal position where the drive units generate the forward thrust, wherein in the horizontal position the thrust axes are located above a central plane of the wing (3).

13. The aircraft of one of the preceding claims comprising at least five drive units (101 - 112).

14. The aircraft of one of the preceding claims comprising at least six drive units (101 - 112).

15. The aircraft of one of the preceding claims wherein each drive unit (101 - 112) comprises a fan with adjustable blade angle.

16. The aircraft of one of the preceding claims wherein all said drive units (101 - 112) are substantially identical.

17. The aircraft of one of the preceding claims wherein each of said drive units comprises an electric motor.

18. The aircraft of one of the preceding claims wherein said drive units are not arranged on a line for controlling pitch and roll of the aircraft.

19. Aircraft, in particular according to one of the preceding claims, comprising

a central cabin (1),

a wing (3) extending at least partially around the cabin,

at least one generator (15) for generating electrical power,

at least one engine (14) for driving said generator (15), and

electrically driven drive units (101 - 112) arranged between the cabin (1) and the wing (3) for generating lift and forward thrust, wherein at least part of the drive units are pivotal from a vertical position to a horizontal position.

20. A method for operating an aircraft, said aircraft comprising at least one generator (15) for generating electrical power, at least one engine (14) for driving the generator, and electrically driven, pivotal drive units (101 - 112) for generating lift and forward

thrust, wherein each drive unit has a thrust axis, said method comprising the steps of

adjusting said thrust axes of said drive units (101 - 112) downwards for generating a lift for lifting the weight of the aircraft for hover flight and

adjusting said thrust axes of said drive units (101 - 112) horizontally for generating a forward thrust for cruise flight, wherein in said cruise flight a lift is generated by an aerodynamic profile of said aircraft,

wherein in hover flight an attitude of the aircraft is controlled exclusively by tilting the drive units and adjusting a thrust of the drive units.

21. Method for operating an aircraft, in particular of claim 20, said aircraft comprising at least one generator (15) for generating electrical power, at least one engine (14) for driving the generator, and electrically driven, pivotal drive units (101 - 112) generating air jets for generating lift and forward thrust, wherein each drive unit has a thrust axis, said method comprising the steps of

adjusting said thrust axes of said drive units (101 - 112) downwards for generating a lift for lifting the weight of the aircraft for hover flight and

adjusting said thrust axes of said drive units (101 - 112) horizontally for generating a forward thrust for cruise flight, wherein in said cruise flight a lift is generated by an aerodynamic profile of said aircraft,

wherein an exit air velocity of the drive units is adjusted to a higher value during cruise flight than during hover flight by decreasing an outlet diameter of at least some of the drive units or by increasing a fan blade angle of a fan of at least some of the drive units.

22. The method of one of the claims 19 or 20 wherein an attitude of the aircraft is controlled exclusively by tilting the drive units and adjusting a thrust of the drive units.

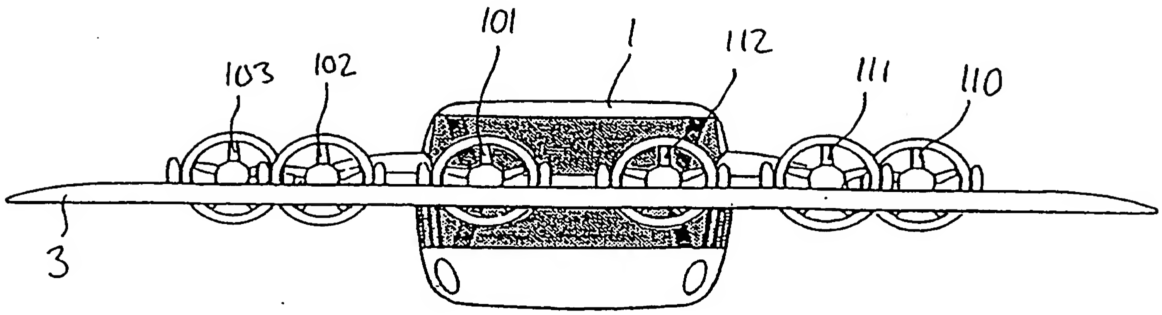


Fig. 1

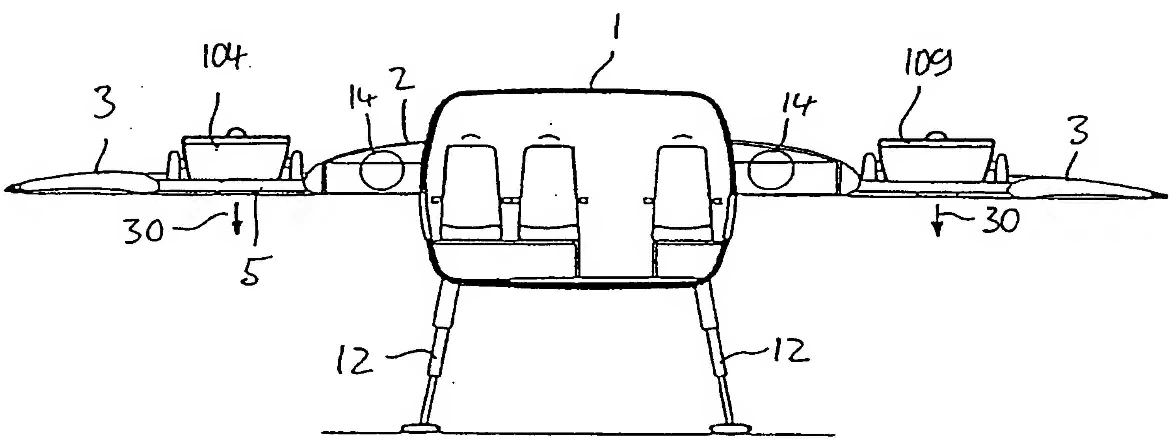


Fig. 2

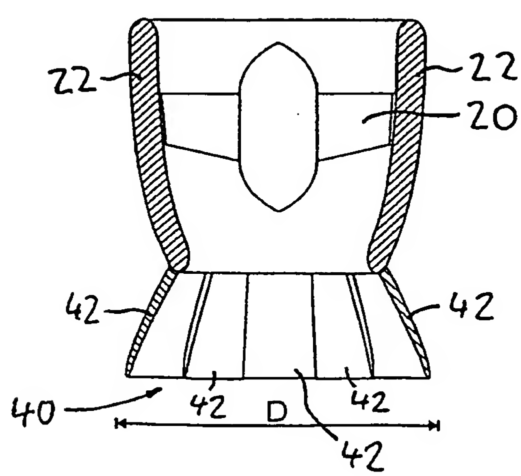


Fig. 4

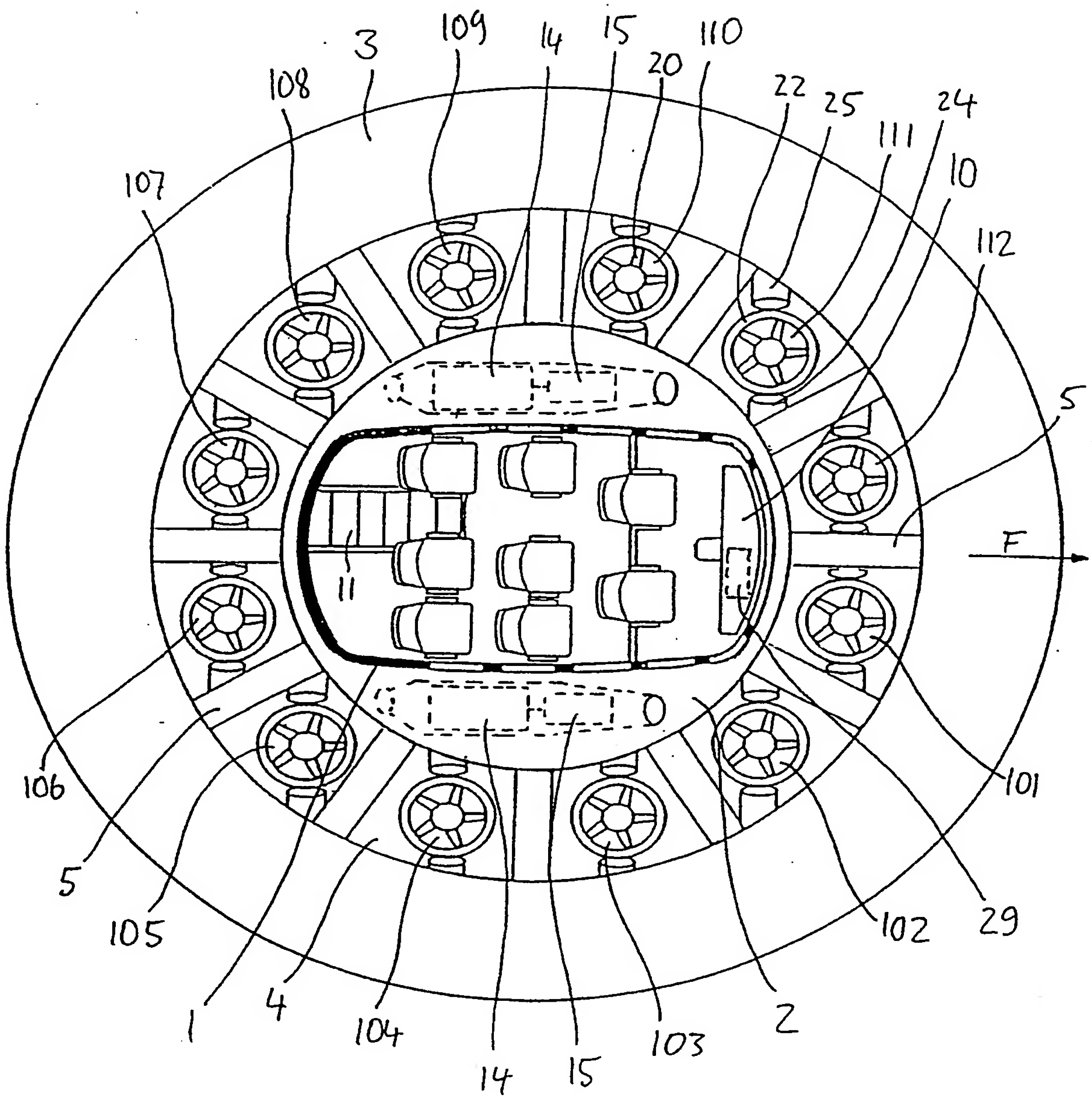

3
108
109
14
15
20
110
22
25
24
111
10
107
112
5
11
F
106
101
5
105
102
29
1
4
104
14
15
103
2

Fig. 3

INTERNATIONAL SEARCH REPORT

Intern   ial Application No
PCT/IB 00/01513

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B64C29/00 B64D27/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B64C B64D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 242 132 A (WUKOWITZ) 7 September 1993 (1993-09-07) column 9, line 10 - line 21; claim 12 column 2, line 48 - line 59 ---	1,17,19, 20
A	US 3 284 027 A (M.MESNIERE) 8 November 1966 (1966-11-08) column 3, line 45 - line 47 ---	1-4,19
A	US 5 895 011 A (GUBIN DANIEL) 20 April 1999 (1999-04-20) the whole document ---	10
A	US 3 614 030 A (MOLLER PAUL S) 19 October 1971 (1971-10-19) the whole document ---	1,8-10, 13-16
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 January 2001	02/02/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Hauglustaine, H

3

INTERNATIONAL SEARCH REPORT

Intern ial Application No
PCT/IB 00/01513

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 3 335 977 A (L.F. MEDITZ) 15 August 1967 (1967-08-15) column 5, line 15 - line 20; figure 18 column 4, line 22 - line 25 ---	1-4
A	FR 1 550 060 A (R. BREINLICH) 20 December 1968 (1968-12-20) page 18, column 2, line 41 -page 19, column 1, line 37; figure 18 page 20, column 2, line 41 - line 60 -----	1

3

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/IB 00/01513

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5242132 A	07-09-1993	NONE	
US 3284027 A	08-11-1966	NONE	
US 5895011 A	20-04-1999	NONE	
US 3614030 A	19-10-1971	NONE	
US 3335977 A	15-08-1967	NONE	
FR 1550060 A	20-12-1968	NONE	